Peters Valley Bloomery Smelting Workshop, July 21-25, 2006

by Bruce Freeman, with contributions by Marshall Bienstock
Photographs by Sean Thorne and Dave Martin

Thursday evening, July 20, I met Marshall at his home and we carpooled up to Peters Valley, where we were rooming at Valley Brook (one of the dormitory houses). Friday morning at breakfast we met Michael McCarthy, who had no trouble recognizing us as blacksmiths.

Mike is a personable character. His bio from the Peters Valley website (PVCrafts.org) reads, "As a demonstrating blacksmith at The Farmers Museum [http://www.farmersmuseum.org/] in Cooperstown, NY, Michael McCarthy has become one of the leading traditional/research blacksmiths in the country. He is developing the iron bloomery program at The Farmers Museum in association with Rockbridge Bloomery [http://iron.wlu.edu] and Wareham Forge [http://www.warehamforge.ca/]. He is a cofounder and director of the first and second annual Iron Smelting Symposiums of 2004 and 2005 in Cooperstown, NY."

Bruce watching, Dick breaking charcoal 2-handed, Mike supervising, Dave and Marshall (hidden) breaking charcoal

After breakfast, the class met at the blacksmith shop. In attendance were Mike, Dick Sargent (artist blacksmith at PV), Beth Slater (this summer's blacksmithing assistant at PV), Dave Martin, Sean Thorne, Philip Kim, Marshall and I. Unfortunately, the weather was not cooperative, being rather rainy on Friday and Saturday.

We started with some preparatory work toward the smelt. We started by grading the charcoal. Dick had ordered in a pallet commercial hardwood charcoal, which proved quite good. Mike had brought down a grading table, consisting of a sheet of expanded metal (diamond-shaped openings roughly 1" wide by 2.5" long), with an sheet of expanded metal (openings roughly 1/2" wide by 1.25" long) beneath at an angle.

We poured a sack of charcoal on the top and whaled on it with wooden mallets, then sieved the pieces on the lower sheet with a hoe, accumulating a box of fines, the rest being the "graded" charcoal for the general charge.

Roasted ore for crushing

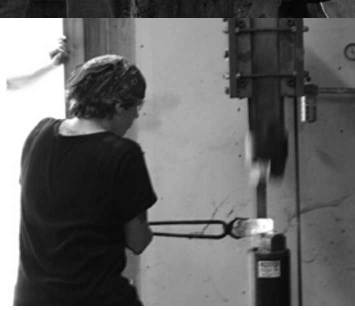
Meanwhile, we broke up some previously-roasted iron ore in a sturdy metal box, reducing it to "sunflower seed" size. We also selected raw ore for roasting. and set up a bonfire in which to roast it. (For further reading on iron ore, see http://en.wikipedia.org/wiki/Iron_ore.

Mike tending the bonfire to roast the ore

L to R -- Ore on pickup truck. Dennis (visiting), Mike, Dick (laying base sheets for bonfire), & Bruce

Bucket of ore, ready for charging into furnace

With some of the preparation work out of the way, we recessed to the blacksmith shop where Mike demonstrated forging a bloom from a previous smelt. To get a large enough fire on an ordinary blacksmith forge, he placed firebricks around the firepot to deepen the fire. Then, with Dick manning a sledge hammer, he consolidating the bloom, which is rather porous as it comes from the bloomery.



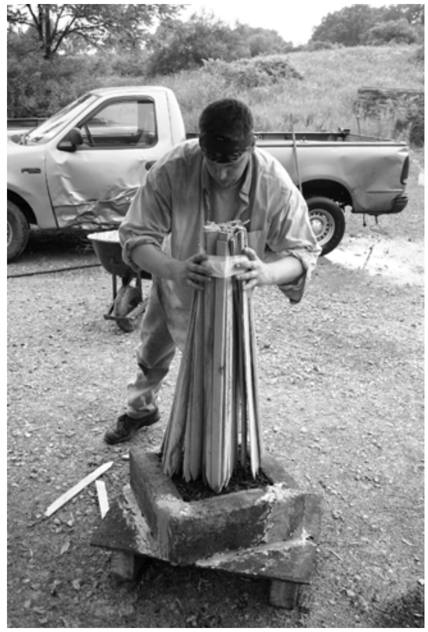
Mike and Dick working the bloom. Beth working the bloom on an air hammer.

This turned out to be akin to a crucible furnace or a small cupola furnace, but with some critical differences. Our bloomery furnace has a floor of charcoal "fines", and a downward-directed copper tuyere (3/8" copper sheet rolled into a conical tube tapering from about 2" down to about 1" ID). The fines act as an essentially inert catch-basin for iron and slag, and the downward-directed tuyere ensure that the iron collected remains in an oxidative atmosphere. The copper tea is thick enough and conductive enough that it does not burn or melt during ordinary operation, providing it is kept clear of slag.

(A cupola furnace, by contrast, has a number of tuyeres above the bottom of the furnace. Hence, these serve only to supply air to the burning coal. The molten, high-carbon iron (i.e., "cast iron") and the slag drop down below this, with the slag forming a protective layer above the iron so that the carbon in the iron is not oxidized away.)

Despite the rain, we began work on a bloomery furnace. We started by setting up a tarp on a peaked pipe framework Dick had kicking around. Then Mike arranged placed a steel plate up on bricks, and arranged four cement blocks on this to make a square, which he then filled with charcoal fines. Atop this, sticks about three feet long were bundled into a conical mandrel and taped together. Gaps were filled in with smaller sticks. Our work was interrupted at this point by dinner and a slideshow by the demonstrators.

Saturday morning we completed the furnace. A couple bags of ball clay and some short pieces of hay were then mixed with water and applied to the mandrel to make a wet clay cone, about 2" thick, about a foot across in diameter at the base and about two feet high. The structure tapered slightly to the top, then flared. The furnace tapers inward on the inside as well so that the ore will tend to drop straight down, away from the walls of the furnace. If hot ore encounters hot clay, the result may be a "wall gromp," - a lump on the interior furnace wall that both wastes ore and constricts the furnace. (For further informtion, see http://www.jernmager.dk/docs/Treatise%20on%20iron%20smelting.pdf.) Mike cut a hole for the tuyere, and also marked an arch about 3" high and about 8" wide on one side.



Mike assembling the mandrel (form) for the furnace.

The base for the bloomery furnace: Four cement bricks on an elevated steel plate, the center filled with charcoal fines.

The partially completed clay furnace and Dave and Marshall finishing clay furnace.

Mike then had us ornament the furnace in various ways. To my surprise, he then removed the wooden mandrel from the furnace piece by piece, before starting a fire inside to cure the furnace. Not to my surprise, the structure soon sagged. Mike attributed this to the very damp weather. As the inside dried and firmed up a bit, he and others carved off the worst of the sags from the outside. Then fired the outside of the furnace, leaving a much firmer structure. Since the furnace had sagged about six inches, we then added clay to the top to build the height back to two feet.

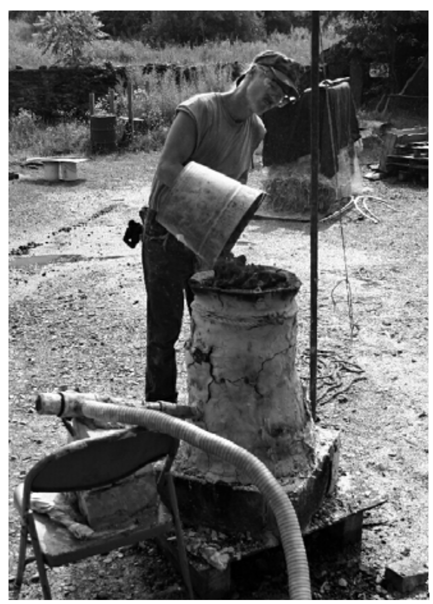
Mike then installed the copper tuyere in the furnace and attached the air plumbing to this. This plumbing consisted of a turbine blower discharging into a 2" flex tube, which supplied the tuyere via a 1.5" plumbing cross. Opposite the flex tube on the cross was a vent, consisting of a simple pivoted plate to open or close this leg of the cross. Perpendicular to these was a removable sight-glass on one leg and a length of steel pipe, tapered on the far end to fit the copper tuyere. (The tuyere must either be stout copper or must be water-cooled steel. Uncooled steel would burn up in the furnace.)

We continued firing the furnace with wood until Mike judged it ready for charging. The furnace developed cracks during the firing, and at first we tried to keep them plugged, but eventually we learned we could tolerate considerable leakage.

We used one bag of upgraded charcoal for the first charge. Mike turned on the blower, setting the vent upstream of the tuyere to a known setting so the blast was predictable. As this burned down, we fed in about six 4 lb charges of graded charcoal, which Mike estimated was sufficient to fill the furnace. At this point, the smelting began. Mike had me keep records of the smelt. Dave made of 4 lb charges of graded charcoal whenever the dome of charcoal at the top of the furnace had burned down sufficiently. At the end of each charcoal charge Marshall charged a variable amount of crushed ore.

We started with small (~1/2 lb) charges of ore along with each 4 lb charge of charcoal. Mike was shooting for a burn rate of 8 to 10 minutes per 4-lb charge of charcoal. If the burn rate was faster than this he would increase the ore charge; if slower, he would decrease it.

A well-formed bloom (note bowl shape) from a previous smelt. Middle ground: The plumbing to supply the tuyere, with tuyere-connection to the right, inlet back, blast control vent front, and sight glass to left.



Charging the furnace with charcoal.

However, as we continued the smelt, pulsing of the blast could be heard and the tuyere showed signs of plugging (visible through the sight glass). Mike tried "rogering" out the tuyere (by removing the sight glass and covering the opening with the hand while running a 1/2 steel "roger" rod down between the thumb and forefinger), with some success. The cause of the problem became obvious when the outside of the furnace began to spall off in places. By this time, there were many cracks in the furnace and small flames were issuing from these cracks. This alone was not a problem, but the spalling on the outside was certainly mirrored on the inside. These little pieces of clay react with the slag and iron, making a treacle-thick slag and ruining the smelt. Mike attempted to rectify the problem by adding iron, in the form of blacksmithing scale, and this did thin the slag. Ultimately, however, the furnace started breaking up and before we'd charged 40 lb of ore we had to abandon the smelt. We continued the blast into the broken furnace to burn up the remaining charcoal.

Later, we examined the residue from the bottom of the furnace. There was some sign of iron, but very little. It was clear that the clay that spalled from the inside of the furnace had ruined the smelt. Mike feels this would have not been a problem if (1) the weather were dryer, aiding the ball clay to dry, and (2) if we'd been using a different ore. Mike felt that the ore we were using, which he and Dick had mined in Virginia from a limestone stratum, was too reactive with the ball clay. Mike recommends using a known furnace type (e.g., a furnace made of a known clay) with a known ore type before experimenting with different materials. He says small changes in materials may lead to large changes in results.

Because of the reactivity of the ore with the clay, Mike decided we'd have another go at building a furnace, but using a different approach. He'd had considerable luck recently with a furnace built from a 12" flue tile. (A "flue tile" is a fired clay pipe, square with rounded corners, used in the construction of chimneys. See http://iron.wlu.edu/Bloomery_Iron.htm and http://iron.wlu.edu/ Coatedtyle%20Construction.htm) Dick was unable to find a dealer that stocked flue tiles that would be open before Monday morning, but Bruce Ringier (NJBA director and PV board member) thought he could get one for us.

In the meantime we cut up a steel bloom (yes, you can make steel in a bloomery) from a previous smelt by heating it in a gas forge and cutting it on a

Dick holding the bloom, Marshall holding the axe, while Dave and Mike strike

wet stump with a sledge-driven axe. Mike and Dick gave us pieces of this bloom to work in the blacksmiths shop. We worked one piece, squaring it off, then folding and rewelding it a few times, Marshall as smith and I as the striker.

Sunday, Bruce Ringier came through with two 12" flue tiles, two feet long. Dick picked these up from Bruce's farm and we started work on them. First you mark the tuyere hole and the arch (90 degrees apart). The tuyere hole should be at the center of one side, seven inches above the bottom. This hole is not round, but elliptical, because the conical copper tuyere is to be with an downward angle sufficient to point at a spot three inches above the bottom of the opposite side. The hole should be about 1/4" wider and 1/4" longer than needed to fit the tuyere tightly when inserted 3" past the inside of the furnace wall and properly angled downward. You rough out with a 1/4" ma-

Two 12" flue tiles supplied by Bruce Ringier. Marshall in the background.

masonry bit in a hammer drill. The arch is 3" high at the center and about 8 5/8" wide at the base, and is "nibbled" out using a Stilson wrench. We prepared both tiles. to this stage.

We then turned one of these tiles into a furnace. Next we mixed up an equal amount of clay and cellulose-insulation fiber with water to make a lumpy paste (it is a mistake to make it too smooth, as the insulating properties of the cellulose would be lost), and applied this to the outside of the tile, that had previously been coated with clay slip. This was covered with a cylinder of chicken wire, the edges tied together, and tightened by appropriate crimping of the loops. An outer layer of the clay mixture finished the furnace. The arch and the tuyere hole were cut out again, and the furnace fired inside and out with wood.

Next, we carried the tile furnace out to the site and set it on the same foundation we'd used for the

Dave and Marshall applying the outer layer of clay

clay furnace- four bricks with charcoal fines filling the space between - such that each corner of the tile was supported by a brick. Since this furnace was of prefired ceramic, spalling would not be a problem. However, cracking began even during the wood-firing stage. That was the reason for the clay -and-chicken-wire coating. (The cellulose fiber is for insulation, but probably adds strength as well.) As we fired this furnace, we poked the clay full of holes with 1/8" wires to let out the steam from the wet clay. When Mike judged the furnace ready, we charged it with a bag of ungraded charcoal, he inserted the tuyere, using clay to seal between the copper and the furnace wall, and started the blast.

I again did the recordkeeping. As before, grad-

The furnace burning charcoal, showing cracks and the holes made to release the steam from the clay.

ed charcoal was added in 4 lb charges. After 28 lb had been added, we began the ore charging. The first ore charges were 1/2 lb, but Mike gradually had us increase the ore charge to 3.5 lb, before stabilizing on a rate of 3 lb ore for 4 lb of charcoal. We maintained this charge ratio for 3.5 hours, with 6.5 to 9 minutes between each charge. The smelt was fairly well behaved. Occasionally, one of use would roger out the tuyere, but little of this was needed.

During this process slag would occasionally run like water from cracks at the bottom of the furnace - a good sign. Mike said this was a high-iron slag that he referred to as fayalite slag (see http://en.wikipedia.org/wiki/Fayalite). We charged much of it back to the top of the furnace. This was partly to reclaim the iron from the slag. However, the

The furnace in blast. Marshall charging ore. Dick viewing the smelt through the sight glass. Mike and three visitors watching.

The furnace in blast. Dave charging coal.

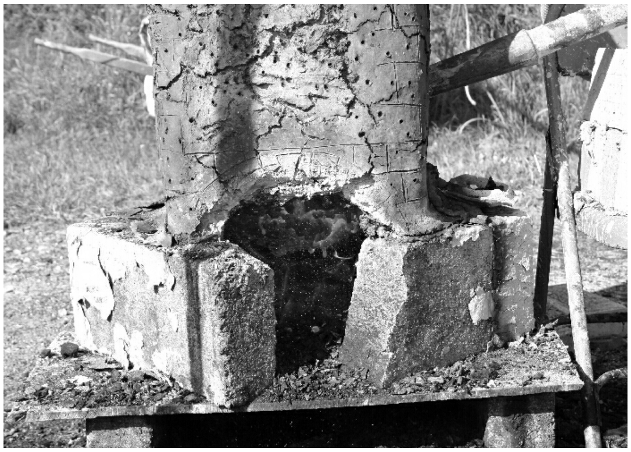
Mike examining the slag running from the furnace

mass of molten material at the bottom of the furnace also acts (in Mike's words) like a "thermal flywheel." This hot mass of slag and wrought iron seems to aid the smelt.

It is my conviction, and I believe Mike's as well, that as the ore is reduced in the furnace stack, the first iron formed is "cast iron" - high in carbon and molten at the furnace temperature. It is only when this liquid, high-carbon iron falls into the direct blast of the tuyere that the carbon in it is oxidized out, leaving wrought iron. This would explain why small changes in smelting conditions can produce wrought iron, steel, or cast iron - a fact observed by Mike and others.

By the end of this smelt, we had charged slightly more than 100 lb of iron ore - the maximum a furnace of this size can handle. Mike expected about 40 lb of iron from this, at best. We stopped charging ore, and began the burn-down of the remaining charcoal. During this time, Mike and Dick opened the arch and built a wood fire under the bloom to keep it hot. After another hour and a half, the charcoal was largely consumed and it was time to break out the bloom. First we tried to do this without wrecking the furnace. Unfortunately, the bloom was firmly attached to the bottom of the furnace and could only be removed by breaking the structure. Therefore, we knocked over the furnace and broke the bloom out from the bottom.

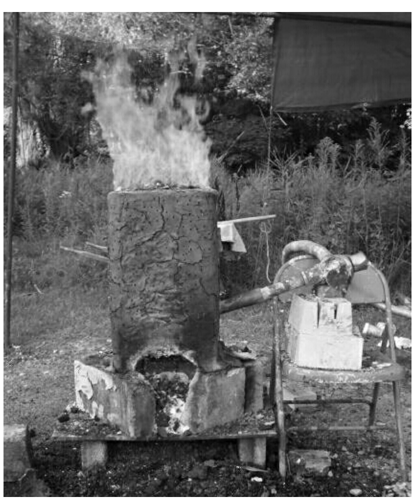
The bloom was immediately lifted onto a wet log and split in about four pieces with axe and



The furnace near the end of the smelt. Half of one brick removed. Bottom of bloom is visible.

sledges. Once these cooled, we weighed them and found the good iron pieces to weigh about 35 lb - not bad at all.

Tuesday, the last day of the class, we spent the morning working on the pieces of the bloom. By building up the forge with bricks, it is possible to get enough heat to heat a large iron chunk. I, however, chose a rather small piece of the bloom and worked it on an unmodified forge, using a hand hammer. I was impressed with how little slag was incorporated in the bloom. However, a welding heat and heavy blows are needed to fuse the bloom into a block of iron, so I desisted till I could get to the Grasshopper Treadle Hammer. (The following Monday, I tried this, but having not built up the firepot with bricks the way Mike did, I couldn't get the necessary heat from the fire without overheating the firepot.)



Mike built a wood fire under the bloom, fanned by a second blower, to keep the bloom hot

Mike finished the workshop with a demonstration of the use of a simple side-draft forge to oxidize cast iron into steel. This process is a crude form of "puddling." Puddling is normally done in a reverbatory furnace, which separates the iron from the fuel, and produces a wrought iron bloom. We worked with the iron in a bed of charcoal, so oxidized the cast iron only as far as steel.

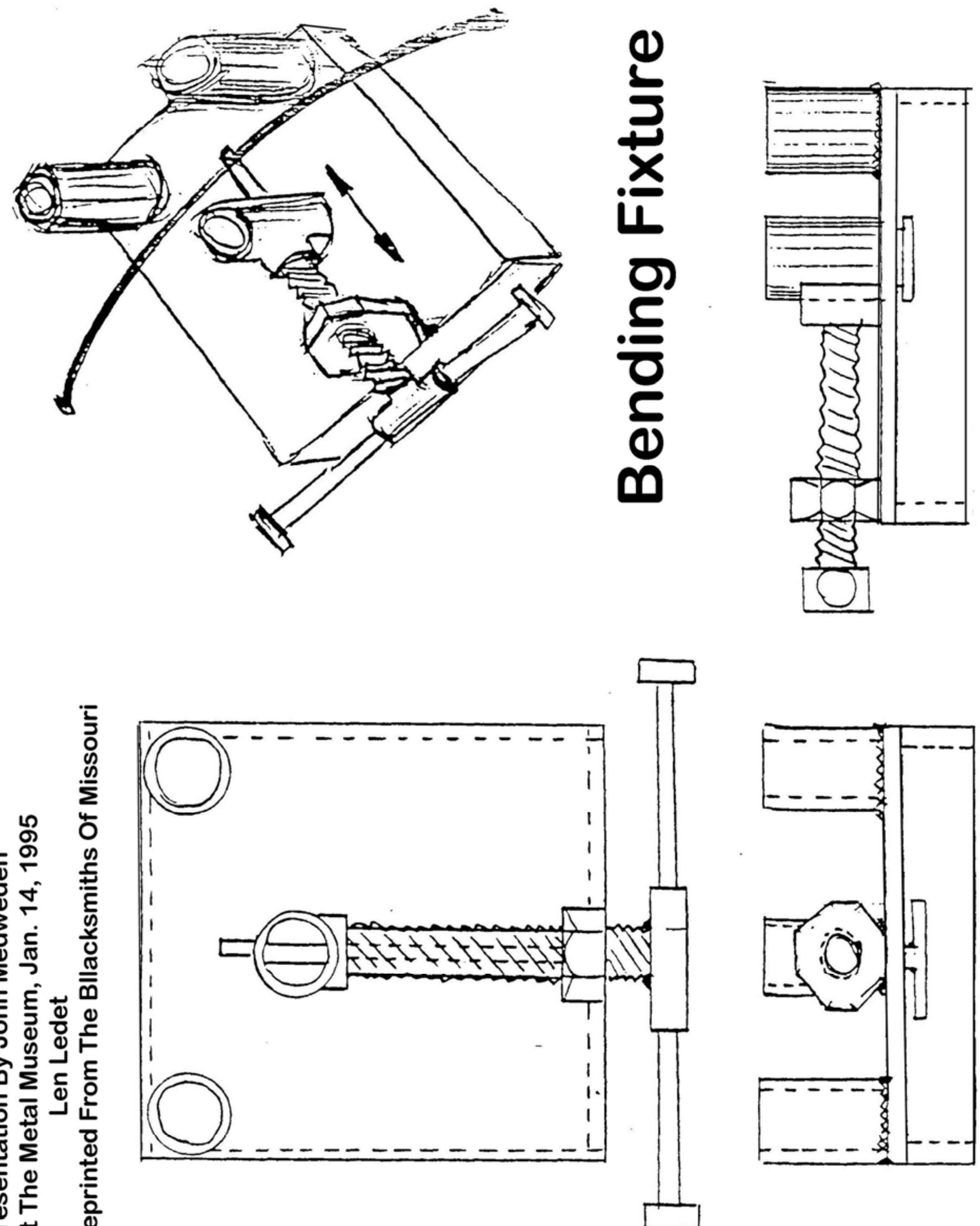
Beth Slater, the Blacksmithing Assistant at Peters Valley, writes:

I'm a student at Marywood University where my concentration is in sculpture. I'm a junior there in Scranton, PA. I took a blacksmithing class here at Peter's Valley with Elizabeth Brim two years ago. I study under Robert Griffith at Marywood. He told me about the summer assistant residency in the blacksmithing with Dick Sargent who he knew 30 some years ago. I applied and was accepted. I wanted to gain skill and knowledge with metals to better my work. So here I am the end of my residency and this experience with Dick, the instructors and students far exceeded my expectations.

I wasn't sure what smelting was when I read through the Peter's Valley workshop catalog for the summer 2006. When I found out what it was I did not think it would be of interest to me. Spending five days making iron did not sound fun until the class started separating the iron and rock. We crushed charcoal, roasted the ore, made not one furnace, but two in this five-day workshop, and finally at the end of it all, produced a beautiful bloom of wrought iron. The hard work, the process, the crew and our fearless leader (who will be at the pig roast and smelt in October) created a wonderful experience for this first time smelter. That's why I'm attending the Peter's Valley Pig Iron Fest in October.

Bending Fixture

Presentation By John Medweden
At The Metal Museum, Jan. 14, 1995
Len Ledet
Reprinted From The Bllacksmiths Of Missouri



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Marshall Bienstock is hosting an open forge in his shop at 7 pm almost every Monday night (Please call ahead on holidays to make sure , (732)780-0871)

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Sunday from 10:00 am to 6pm.
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Northeast Blacksmiths holds its meets twice a year at the Ashokan Field Campus in New York State.
The Ashokan campus is located in Olivebridge, N.Y., several miles west of Kingston, N.Y. The meets are held the first weekend in May and in the first weekend in October every year. The main demonstration is in the blacksmith shop and there is a "Hands On" workshop for beginners. A main demonstrator is brought in for each meet, food and bunk-house style lodging are provided as part of the cost of the weekend long meet.

Contact : Tim Neu
to register for hammer-ins
or subscribe to the newsletter;
Tim Neu, Ashokan Field Campus,
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